CERAMICS

OCTOBER
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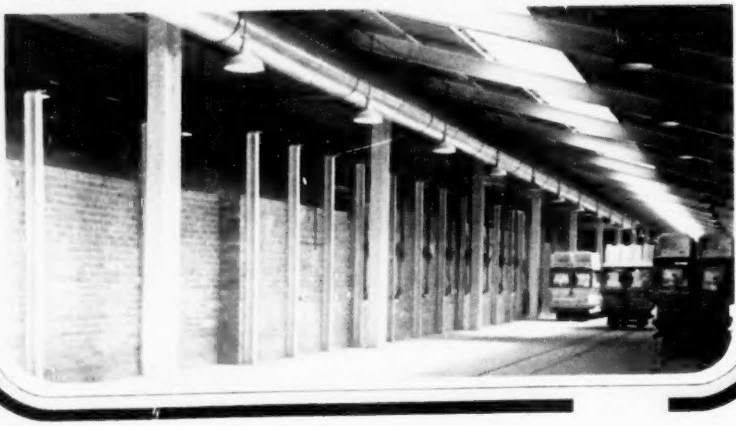

CERAMICS

OCTOBER, 1952

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CERAMICS

WILFRED F. COXON

M.Sc., Ph.D., F.R.I.C., F.I.M., M.Inst.F.

Managing Director of the Publishers, Arrow Press Limited

Arrow Press Limited (Publishers of "Ceramics," etc.)

WILFRED F. COXON, M.Sc., Ph.D., F.R.I.C., F.I.M., M.Inst.F.

Managing Director of the Publishers, Arrow Press Limited.

Born on Tyneside, 1911. Educated at Rutherford College, Newcastle-on-Tyne, and the Universities of Durham, Nottingham and London.

Graduate of London University. Bachelor of Science, First Class Honours, Chemistry, 1932.

Master of Science (London) by research on Silicones, under the late Professor F. S. Kipping, F.R.S.

Doctor of Philosophy (London) by research under Professor G. R. Clemo, F.R.S., King's College, University of Durham.

Works Chemist, Turner & Newalls Ltd. Research Chemist, Imperial Chemical Industries Ltd. Senior Science Master, King Edward's Grammar School, Birmingham. Lecturer in Applied Chemistry, The Polytechnic, Regent Street, London.

At the outbreak of war, joined the Air Ministry and subsequently the Ministry of Aircraft Production. Eventually promoted Principal Technical Officer.

Here responsible for research and development on pyrotechnics and incendiaries, and ultimately the research and development of the special armament equipment used by the Pathfinder Force of Bomber Command and the American Army Air Force.

Awarded £1,500 by the Royal Commission on Awards to Inventors for the Target Marking Bomb used by the Pathfinder Force and the U.S.A.A.F.

On leaving the Ministry in 1946, built up a useful consulting practice covering the gas industry, and also appointed Technical Advisor to the Royal Swedish Air Board.

Edited and broadcast a magazine series with the British Broadcasting Corporation entitled "Industrial Britain."

Freelance contributor to Technical and National Press.

Founder Editor of "Ceramics." Appointed Director of Arrow Press in 1951.

Ceramics

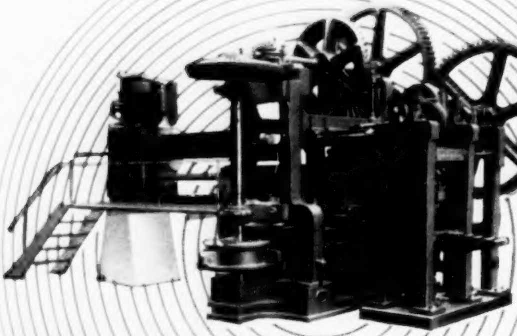
VOL. IV OCTOBER, 1952 NO. 44

THE POLICY OF "CERAMICS"

THIS publication was introduced because it was thought that in Britain there was no coverage given to the technology of the ceramics industry in its broadest sense. Its introduction was primarily to attract and provide interest value for the works executive grades—it was not introduced as an attempt to publish highly academic papers for the scientist and research worker, because the various professional associations and institutions cover this field extremely well. It was, rather, to be a résumé of practical achievements in the field of ceramics technology.

Progress has been made and now the publishers have no doubt whatsoever that the journal is fulfilling a useful purpose.

CERAMICS dovetails into the general policy of Arrow Press Ltd., which can be summarised as follows. There is a tendency today towards power resting in the hands of the economist and politician, who have copious suggestions as to how the national wealth should be dispensed. On the other hand, it is productive industry which has to earn that wealth and in this respect one refers to productive industry in the sense of management and men, irrespective of whether the industry is nationalised or not. Both management and men are producing the nation's wealth, yet because of our peculiar political drift they are having less and less say in the distribution of that wealth. In fact, because the economic and political leader does not have the day to day responsibility of earning the nation's wealth he is becoming most reckless in the methods he suggests towards its distribution. In fact, this recklessness is reflected in various measures which are day by day rendering the task of production considerably more difficult. And when productivity faces such hazards it is as well to remember that the direct consequence is a reduction in the standard of living of the community, which the bland economist and politician offers to save by short-term measures of popular expediency, summarised in the



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phrase "Live for today . . ." Most assuredly, unless industry does get a chance to express its case politically and economically, the end of the phrase, "For tomorrow we die," is likely to be realised.

Thus the leader policy of Arrow Press publications is to continue to be directed towards a resurgence of the strong case of industrial management and men. Editorially our lead will always be towards ensuring that their case is pre-eminently presented on all aspects of interest to them. We do not even claim to attempt to be impartial in this respect. The policy is one of distinct partiality to those working in and responsible for industrial productivity. That is, indeed, fundamental in our policy and it will be pursued relentlessly.

Mr. Mervyn R. Harley, J.P., a new director of Arrow Press Ltd., who is taking over the commercial management of "Gas Times." Well known in London, he was responsible for founding and editing the "Wembley News" from 1923 until recently. He has been managing director of the "Wembley News" since 1933. Was trained as an economist in the London School of Economics. Elected to the Wembley Council in 1922 and became its chairman in 1933. Elected Alderman on the creation of the Borough of Wembley in 1936. Served on the Middlesex County Council during the war and is a past president of the Wembley Chamber of Commerce and the Wembley Rotary Club. Was appointed to serve on the Bench in 1942.

THE FUTURE OF FUEL

by **ARGUS**

BOTH the gas and electricity authorities state in the Ridley Report that they are determined to capture as much of the industrial load that their respective organisations can attract. In fact, reading the Ridley Report one can see through this a tremendous desire on behalf of both gas and electricity to struggle to present their case. Factually, of course, both industries have placed themselves under the category of accusation as monopolies and when they put forward price increases, even though their case may be quite justified, nevertheless there is a disquieting assumption that because they are monopolies, price increases are that which one would expect. In actual fact, since nationalisation, as far as the user is concerned, that is all he has had.

With this background some comments at the Labour Party Conference at Morecambe made interesting reading. They accepted the following resolution: "That this Conference recommends that the organisation of nationalised industries should be examined and particular consideration given to securing greater accountability to Parliament, the training of workers in administration, the methods of giving to workers a greater share in the management of industries and the development of alternative forms of public ownership and their co-ordination." During the course of speechmaking on this resolution, Mr. J. Braddock (West Derby, Liverpool) said that all nationalised industries, except the mines, offered grave dissatisfaction due to faulty administration. He accused the Labour Government, responsible for the nationalisation Acts, of handing over groups of national executives in controlling positions belonging to the "old ruling class." What is more important, he went on to suggest that if these executives had not sabotaged the nationalised industries the results they had produced made it look so much like sabotage that it was difficult to prove that it was not.

It is important to remember that this ebullition came from a representative member of the Party whose Government had introduced the nationalisation Acts. No credit is given to the various executives in the present nationalised industry who hated the very idea of nationalisation. They had the opportunity of having their skill and knowledge and using it within the industry or attempting to go elsewhere and leave it to stagnate without their skill.

If responsible people like Mr. Braddock are to bandy about for popular appeal statements such as this, it is of little help to the industries concerned or indeed to his supposed "cause." Peculiarly enough, Mr. Braddock chose the mines as being the nationalised industry which gave least dissatisfaction. Yet Mr. J. B. Thomas of the London Labour Party said there had been over-centralisation—and since the mines is the most over-centralised of all the nationalised industries, one would imagine that Mr. Thomas did not consider that the mines were as effective as Mr. Braddock had suggested. Then Mr. Turner of the National Union of Railwaymen came along with the almost undisguised suggestion that the nationalised industries were run by people who were deliberate saboteurs.

That seems to be about the sum total of the Labour Party's approach to the question of nationalisation. The point is that they either wish to obtain the best from nationalisation, which has been the theme song of the Labour Party almost since its inception, or they do not. If they wish to obtain the best in the national interest it seems rather absurd to alienate those who have worked for these industries, by such infamous allegations

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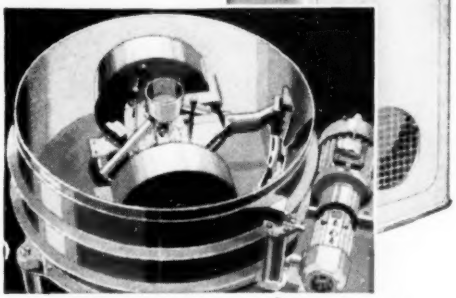

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simply to catch the cheap, fleeting spotlight of popular acclaim at a Political Party Conference, without considering the results of their action.

Bear in mind that those now running the nationalised industry, which include quite a considerable number of pro-Labour characters, have just had presented to them the Ridley Report. The recommendations said, more or less, that the country cannot trust the present people who are running nationalised industry. By their recommendations there is the undisguised suggestion that these people are not giving the consumer a fair break. Instead, the Committee recommend that an independent Tariffs Committee should be appointed. Not, of course, that this Tariffs Committee should have to accept responsibility for the fuel industry—whether it runs at a profit or a loss is of relative unimportance to this Tariffs Committee. They can always be assured of being on the right side of the fence, because all they have to do is clamour to the Minister for reduced tariffs, which at first sight seems popular and which, because the Minister is a political head, he will have difficulty in refuting, and the Committee with authority without responsibility will get away with their argument.

Excuse for Failures

On the other hand, these men running the nationalised industry are dragooned because for popular appeal the Tariffs Committee can demand low prices for fuel, and as a result of this the nationalised industry may declare a loss and the unfortunate executives therein may be accused most vituperatively in the Press of gross inefficiency. If, as Mr. Braddock suggested at Morecambe, these men wish to sabotage nationalisation what better opportunity is afforded them than to give full reign to the recommendations of the Ridley Committee when they will have an excuse for the failures of the industry which is second to none.

But if the consumer gets cheap fuel because of the Tariffs Committee, what does it benefit him if the industry runs at a loss and as a result the industry cries out for a subsidy. Subsidies come only from the Chancellor of the Exchequer and the Chancellor, in turn, only draws his revenue from the consumer. Thus apparently cheap fuel might appear in the ultimate balance sheet as very expensive.

Strengthen Consultative Councils

One can hazard a guess at this impartial and independent Tariffs Committee—the odd Professor to lend tone; the nouveau Peer to lend dignity; the place-seeking County Councillor or Alderman, who panders for votes; the representative of industry whose sole idea is to obtain apparently cheap fuel; of course, the economist. None of the people therein have any responsibility, any more than the delegates at the Morecambe Conference, and one can expect their opinions to be equally irresponsible. Already the nationalised industries are accountable via their consultative and consumer councils to the public. The important thing, surely, is to strengthen these. These consumer councils should be more representative of the people who use fuel. There is a simple question to the Ridley Committee, individual by individual. Would any member of that Committee accept the individual responsibility for running any enterprise presumably at a profit, if the price for that service they rendered were to be assessed by a number of people who did not have the responsibility for running the enterprise concerned? No one but a fool or a charlatan would shoulder a responsibility such as this.

The Minister has his heads of the nationalised industry either appointed by, or approved by himself. If he accepts them they must be his advisors and any planning committee must include them plus himself. It is to that committee that consumers must have the right to appeal, and the Minister must not try to shelter from the necessity of formulating his own opinion. If once we depart from this and the public vests its interest in fuel in a Committee which does not have responsibility for producing and distributing fuel, then the Committee can escape by saying "This is what we suggest," and the nationalised industries can escape by saying "But what they suggest is absurd"—and the public will continue to pay!

METAL OXIDE REFRACTORIES

SPECIALLY CONTRIBUTED

MODERN engineering techniques are demanding the use of higher and higher temperatures, and consequently the demand for refractories which will give satisfactory service under these conditions is increasing. At present the materials which will stand temperatures above 1,700° C. are limited to the metal oxide refractories. E. Rosenthal (Pottery and Ceramics — Pelican Books, 1949), gives the following information on metal oxide and other refractories, Table 1.

Nevertheless considerable research interest is being taken in them at the present time, and it has often been found in the past that a demand for a material stimulates the search for new sources and new methods of extracting it, which ultimately lower its selling price to a more reasonable level.

Alumina, Al_2O_3

At present this is the most widely used of the oxide refractories. It can be made in porous and non-porous forms using either fused or calcined alumina as the starting point. In general the refractory oxides have no plasticity, and the methods of shaping therefore, are restricted to casting and pressing (and to some extent extrusion) with or without the aid of binders to confer green strength. Some plasticity can be induced in alumina by boiling with dilute acid and this is almost universally practised in making pure alumina ware.

Details of the methods used in Germany have been published[2]. The alumina is milled in steel ball mills with steel grinding balls to a fineness

TABLE 1.

	Melting Pt. ° C.	*Limit of Application ° C.*
Alumina	2,050	1,950
Magnesia	2,800	2,400
Beryllia	2,570	2,400
Zirconia	2,700	2,500
Thoria	3,050	2,700
Lime	2,570	2,400
Silica	1,710	1,680
Zircon ($ZrO_2.SiO_2$)	1,900	1,750
Spinel ($MgO.Al_2O_3$)	2,130	1,900
Mullite ($3Al_2O_3.2SiO_2$)	1,810	1,700
Sillimanite ($Al_2O_3.SiO_2$)	1,810	1,700

Some of these oxides are comparatively rare and their present cost would prohibit large scale use.

J. M. Chesters[1] has quoted the following prices for raw materials for 9 in. bricks made from metallic oxides (after R. E. Birch, *Eng. Exp. News*, Ohio State Univ., cf. also Refr. J. **22**, 56, 1946).

Material	*Cost in Shillings*
Beryllia	25.0
Magnesia	0.5
Alumina	0.55
Thoria	185.0
Zirconia	14.0

Courtesy: The Morgan Crucible Co. Ltd.

A representative collection of pure oxide ware crucibles, tubes, boats and trays

of 65 per cent. under 5μ and none coarser than 20μ. This is checked by the usual tests. A typical charge is given as 200 Kg. alumina, 200-300 litres water, and 300 Kg. of steel balls 20-25 mm. dia. The mill dia. is 1 m. and the length similar. It is worked at 45 r.p.m.

After milling the material is extracted with 6 per cent. hydrochloric acid to remove iron. This is done in wooden vats heated with steam, and stirred with a wooden paddle. After settling the alumina is washed three or four times with water by decantation, and the sludge stored in stoneware containers. For dry pressing it is dried out.

A variation of this procedure is to grind the calcined alumina with water in a rubber-lined ball mill, using sintered alumina plates as grinding media. This is continued for two days till the particles are all finer than 5μ. The alumina is then obtained by filter pressing and drying in air for eight days.

Extrusion of Alumina Ware

Tubes below 30 mm. dia. can be extruded. For this purpose the use of a binder appears essential. Gums such as tragacanth and brown gum (in xylol) have been recommended. Another ingenious method is to use an alumina gel as the binder. This is obtained by mixing the hydrated alumina with 80 per cent. (by volume) concentrated hydrochloric acid and slowly diluting with cold water. Heat is generated in the process and on cooling a stiff gel is formed. One part by weight of this is mixed with four parts of the dry ground alumina in a rubber-lined mixer and sufficient water added to give the right consistency for extrusion.

Some workers de-air the slugs before extrusion through hardened steel dies. Both horizontal and vertical extrusion is done, smaller tubes being usually extruded vertically. Larger size tubes and crucibles are cast, using an aqueous slip acidified with hydrochloric acid.

Casting and Pressing

One recipe given is 100 Kg. ground calcined alumina, 45 litres of water, and 5 litres of strong hydrochloric acid (one part of water to four

TABLE 2.

Temp. °C	Crushing Strengths Al_2O_3	$MgO.Al_2O_3$	ZrO_2	Kg/Cm² (× 10³) ThO_2	BeO
20	30	19	21	15	8
400	15	—		11	—
500	—	14	16	—	5
600	14	—		6	—
800	13	12	—	5	4·5
1,000	9	—	12	3·6	2·5
1,100	6	6	—	—	—
1,200	5	5	8	2	2
1,400	2·5	1·5	1·3	0·4	1·7
1,500	1·0		0·2	0·1	1·2
1,600	0·5	0.6	—	—	0·5

parts of concentrated acid). The slip is usually de-aired to remove entrapped air before casting. To assist in the development of fine grained structure in the ware 0·5 per cent. of magnesium fluoride is sometimes included in the alumina batch. This is usually mixed with the slip.

R. Scott gives the following recipe for casting alumina ware. The raw material is calcined alumina (80 per cent. through 200 B.S. sieve). This is ground in a ball mill to finer than 20μ and most of it finer than 5μ. Iron from the grinding is leached out with acid and the slip has a specific gravity of 2 (70 per cent. solid) and contains 1 per cent. by weight of acid. This is de-aired (1-2 cm. Mg.) before use, and the articles cast in plaster moulds and calcined to 1,800° C.

Dry pressing is carried out in steel dies using 1-5 per cent. of a binder. Gum tragacanth and brown gum have been recommended. Polyvinyl alcohol has also been used and a typical pressing batch is given as follows:

33 alumina (acid treated) 64 mesh (approx. A.S.T.M. 20 mesh).

25 dried residue from 400 mesh screen.

42 dried turning scrap.

This is mixed with 12 per cent. of a polyvinyl alcohol solution in water (8 gm./litre) and finally screened successfully through 20, 28 and 48 mesh (A.S.T.M.) screens. Pressing is done at about 4,000 p.s.i.

Firing is at temperatures in the region of 1,800° C., though some firms

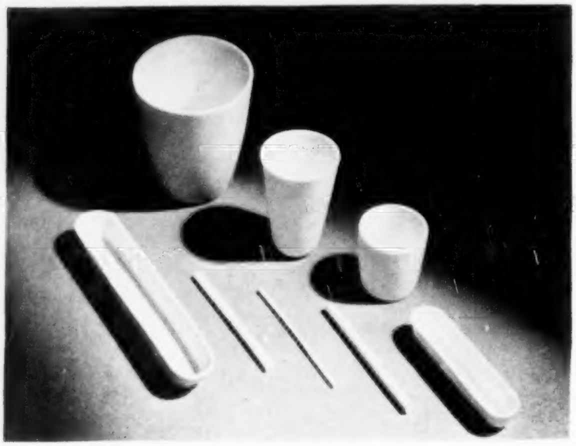
TABLE 3.

Temp. °C.	Tensile Strength Al_2O_3	Kg/cm² $MgO.Al_2O_3$	BeO
20	2,650	1,350	1,000 (estimated)
300	2,360	—	—
500	—	—	780
550		960	—
805	2,400	—	—
900		760	490
1,050	2,380		—
1,130	2,210		—
1,140	—	—	145
1,160	—	430	—
1,200	1,300		
1,300	—	80	45
1,310	450		—
1,400	300		—
1,460	110		—

use temperatures above 1,900° C. This is usually done in periodic kilns, gas fired. Fused pure magnesia is used commonly as a refractory in these kilns, though even with this the life is not long, and repairs to the lining are commonly required after ten to twelve fires.

High Strength of Sintered Alumina

J. H. Chesters states that high purity of the raw material and control over the furnace atmosphere is necessary to avoid local grain growth of sintered alumina. He points out that its strength is 150 times that of normal firebrick, and around 1,200° C. it is one of the strongest materials known. Its use as a cutting tool has also been mentioned by A. L. Roberts and F. Singer. The compressive strength of sintered alumina



Further examples of pure oxide ware

(Courtesy: The Morgan Crucible Co. Ltd.)

fired to cone 40) has been determined by E. Ryschkewitsch over a range of temperatures for a variety of pure oxide refractories and the values are given in Table 2.

Tensile tests were also carried out on sintered alumina, sintered spinel ($MgO.Al_2O_3$) and sintered beryllia (BeO) fired at the same temperature (S. cone 40 approx. 1,900° C.). The results were as Table 3.

The same author determined modulus of elasticity over a variety of temperatures. It was found to depend considerably on the diameter of the test specimens, but a diameter of 0.08 in. gave the highest results. The values given below are estimated from the curves plotted off the results. The specimens were fired as for the other tests.

The other properties of sintered alumina as given by W. H. Henson are:

P.C.E.—Cone 33-41.
True spec. gravity—3.8-4.0.
Approx. wt. of 9 in. brick—11 lb.
Linear coe'f. expansion/° C.—7×10^{-6} (20-1,000° C.).
Thermal conductivity — BTU/Hr/sq. ft./in./° F.—18-20 at 2,000° F.
Mean sp. heat (C.G.S. units)—0.174-0.304 (32-1,832° F.).
Deformation under load—1-2% at 2,732° C. (50 lb./sq. in.).
Shrinkage—None at 2,732° F.

Pure alumina refractories are used for lining furnaces, and for making muffles to stand temperatures up to 1,900° C. On account of its high dielectric strength at high temperatures and resistance to thermal shock recrystallised alumina is used for sparking plugs. It has also been used for gas turbine blades, for crucibles and for laboratory ware.

Beryllia BeO

The raw material for beryllia refractories is the mineral beryl $3BeO.Al_2O_3.6SiO_2$ which occurs in pegmatites. Commercial qualities of beryllia containing 99.8 per cent. BeO are now available. F. H. Norton gives the following properties:

M.Pt.—2,510° C.
Sp. gravity—3·0.
Hardness (Moh's)—9·0.
Thermal conductivity—Very high.
Thermal shock resistance—Excellent.
Mean thermal expansion (up to 1,400° C.)—9·3 × 10^{-6}.

of low temperature beryllia were blended with water and tamped into a mould. Organic binders were used for complicated shapes. W. H. Swanger and F. R. Caldwell used a calcined beryllia passed through a 100 mesh screen and a solution of 4 gm. beryllium chloride in 100 ml. water for moistening before tamping or pressing.

TABLE 4.

	Modulus of Elasticity			*Kg/cm² (× 10⁶)*	
Temp. °C.	*Al_2O_3*	*$MgO.Al_2O_3$*	*BeO*	*ThO_2*	*ZrO_2*
Room Temp.	3·9	2·4	3·2	1·5	1·9
800	3·6	2·0	2·8	1·3	1·3
1,000	3·2	1·6	2·3	1·2	1·3
1,200	2·8	1·1	1·4	0·9	1·2
1,400	2·3	—	—	—	1·0
1,500	1·8	—	—	—	0·9

The oxide is volatile at 1,800° C., and crucibles heated at that temperature lose weight at a comparatively high rate. D. Kirby (loc. cit.) gives the specific heat as 0·29. The melting point is about 500° C. higher than fused alumina, the thermal conductivity is higher, and the thermal shock properties are better. Its electrical resistivity at high temperature is high and it has been used in tungsten wound furnaces operating at 2,350° C.

It is resistant to fused alkalis and reducing agents, e.g., metals and carbon.

The small amounts of the material available hitherto has restricted its use to special applications such as crucibles and laboratory ware, furnace tubes, and gas turbine blades. The toxicity of the oxide is also a factor to be watched in using this material.

Making Methods

F. H. Norton (loc. cit.) has described methods of making small articles with beryllia. Pure beryllium hydroxide was used as the starting point, and was calcined to either 1,200° or 1,800° C., depending on the crystal size required. The bigger crystals were obtained at the higher temperature. Shaping was by (a) ramming, (b) casting, and (c) pressing.

Beryllia tubes can also be extruded using 4 per cent. of gum tragacanth as a binder.

For ramming a mixture of   by weight of high temperature grog and

For casting Norton used a similar method to that already described for alumina castings. The calcined beryllia was ground in a ball mill and the iron leached out with acid. The aqueous slip had a specific gravity of 1·9-2·0 corresponding to 37-33 per cent. water and the pH value was maintained at 4·5-5·0.

Carbowax Used As Binder

For pressing the dry powder was mixed with 14 per cent. of Carbowax 4,000, added as a 20 per cent. aqueous solution. The mass was partly dried at 80° C. and rubbed through a 14 mesh sieve. It was then dried out and pressed between steel dies at 20-30,000 p.s.i. using a die lubricant.

The wax requires heating carefully to remove it without cracking the ware and 8 hr. were occupied in raising the temperature to 500° C. Cast pieces were pre-fired to 1,000° C. to give strength. Final firing was carried out at 1,800° C., the temperature being held at this point for 30 min. Small pieces are fired in about 4-5 hr.; larger pieces take longer. If porous ware is acceptable the firing temperature can be lowered to 1,500° C.

Zirconia Refractories. ZrO_2

The cheapest raw material for this oxide is zircon sand, which is found on the beaches of Australia and Florida.

This is mainly the silicate and a typical analysis shows that it contains about 65 per cent. of zirconia (ZrO_2). Baddeleyite, which contains over 80 per cent. of the oxide is found in Brazil, but is a more expensive raw material. Zirconia melts at approx. 2,700° C. and can be used up to 2,500° C. Its other properties (D. Kirby loc. cit.) are:

Hardness 6·5 (Moh).
True sp. gravity 5·5-6·0.
Specific heat 0·15.
Thermal expansion 5·5-6·5 × 10^{-6}.

Stabilisation of Zirconia

A difficulty in using zirconia was that it underwent a reversible change in crystal form at about 1,000° C. which could cause cracking. It was found in 1929 that the material could be stabilised by small additions of magnesium, calcium, or yttrium oxides.

Fused stabilised zirconia was first made in America in 1946 and cost 14s. per lb. Further research has reduced this price to about 3s. 6d. The product contains 94-95 per cent. zirconia, CaO 4-5 per cent., SiO_2 0·14-0·75 per cent., Fe_2O_3 0·2-0·7 per cent., TiO_2 0·22-1·00 per cent. The material is made up in two forms (a) porous (50 per cent. porosity or higher) for insulation, (b) a dense form.

Zirconia lacks plasticity even when ground, and shaping is commonly done by pressing with pressures up to 6,000 p.s.i. using an organic binder e.g., dextrin. After drying the articles are fired to 1,770° C. to 2,000° C.

W. H. Swanger and F. R. Caldwell have described a method of slip casting and pressing zirconia crucibles (c.f. also P.D.S. St. Pierre). In casting a slip is made of zirconia, china clay and water in the proportions 1,000 gm. purified zirconia, 40 gm. china clay and 500 ml. water. After drying this is fired at 1,700° C. For tamping and pressing the oxide is moistened with a 2 per cent. solution of zirconium chloride ($ZrCl_4$), which is used as a binder and no clay is added. Thorium and magnesium chlorides in similar concentrations can also be used.

The properties of the fused stabilised material (after N. Clarke Jones) are as follows. Table 5.

TABLE 5

Melting Point	2,550-2,600° C.		
Specific Gravity (g./cm.³) True	5·6		
Bulk (dense variety)	4-4·4		
Bulk (insulating)	2·5		
Thermal Conductivity (k) (B.T.U./hr./sq. ft./in./° F.) at:			
	1,200° F.	1,600° F.	2,000° F.
Dense (28% porous)	5·0	5·5	6·0
Insulating (51% porous)	3·75	4·0	4·4
Insulating grain (68% porous)	2·25	2·5	2·75

This indicates considerably lower thermal conductivity than fused magnesia and alumina. The load bearing is good at high temperatures failure occurring at 2,110° C. with a load of 10 p.s.i. and at 1,950° C. with a load of 40 p.s.i. The stabilised material shows good resistance to thermal shock and is highly resistant to oxidising and moderately reducing atmospheres. Chemically it shows low reactivity at high temperatures.

Use As Electric Resistor

An interesting application is as a resistor for high temperature furnaces due to the fact that its electrical conductivity is good at high temperatures (c.f. W. L. German). Among its other uses are for kiln furniture to stand high temperatures, for chemical plant and for liners for jet and rocket motor tubes and in gas turbines. V. H. Stott and A. Hilliard have shown that zirconia shows excellent resistance to coal ash slags and that its use, either alone, or as a facing on the walls of furnaces operating at high temperatures, is to be recommended.

Zircon Refractories

J. M. McKee and A. M. Adams have described a method of preparing slip cast zircon (zirconium silicate) refractories (c.f. also Titanium Alloy Manufacturing Co. Ltd., Brit. Pats.

(*Continued on page* 119.)

DECORATING GLASS AND POTTERY

by

L. DUBUIT

THE manufacturers of ceramics, produce a range of decorations which are extremely rich and varied, used both for artistic productions and in industry, and which lead to many different forms of application. All use enamels in very fine powder form, generally mixed with a solvent appropriate to the process employed.

We are going to quickly run through the different processes which have been utilised up to now, and of which certain find, and always will, their place in artistic decoration.

Decoration by Brush

Decoration by brush is without doubt the oldest form of glass decoration. This is almost entirely an artistic process, and in these days considered too slow for general commercial use.

The enamels are mixed with turpentine, then painted with a brush on the various surfaces to be decorated. It is by this means that bands and lines are put on to glass and pottery, using colours which can be fired.

In the last few years, machines have been designed which will do this work. With these machines, the colour is usually applied to a circular object by means of tracing discs or wheels. The colour used is the same as above, with very often the addition of a few drops of oil of turpentine. Another method suitable for small runs is to use a stencil made of tin and to apply the colour over this stencil by means of a short-haired brush.

Rubber Stamp Method

This is a simple and easily applied method for any suitable design. However, this process has serious limitations, the principal being the lack of density in the colours, due to the extremely thin coating of ink which is deposited. It is for this reason that the method is combined with the powdering process, and is carried out in the following manner. Spread a thin covering of fatty oil by means of a roller on a glass plaque, then with the rubber stamp (generally mounted on soft rubber to increase the "give") transfer some of the fatty oil to the object to be decorated; this being done, the impression made is powdered with the desired colour, which adheres to the tacky substance put on. In pottery decoration this method is mainly used for flat surfaces.

Offset Process

When printing round objects, a rubber stamp is difficult to use effectively. This difficulty has been overcome by printing a cylindrical article by the offset process, by which an impression from a block is taken off on to a rubber pad. This impression is also made by using a fatty ink with an oily base, having strong colouring properties. In order to print the object, it is rolled on to the rubber pad which has already received the impression from the block. Once the cylindrical or conical object has been printed, it is powdered in the way referred to above.

Transfer or Copperplate Engraving

For many years, china and glass have been decorated by transferring

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An extract from a paper presented on 17th June, 1952, to a meeting of pottery and glass manufacturers at the "Maison de la Chimie," Paris. Translated by E. A. Kuttall (London agent: Dubuit Machines, Park Avenue, Twyford, London, N.W.10).

Machine for printing the centre and border of plates in succession

the design on to the ware by means of an engraved plate.

This is not a rapid method, and it is for this reason that it has been partially replaced by the silk screen process in a great many modern factories. The plate can be of either steel or copper. In the latter case, the plate is covered with nickel or chromium, after engraving, in order to give it a longer life. The engraving is done, either directly, or by acid. The colour to be used is mxed with oil. A thick paste is obtained which it is necessary to heat when using.

The engraving plate is likewise heated, and when hot, is covered with the ink which is spread over the whole surface with a very fine flexible metal blade. After the excess ink has been removed, the transfer paper is applied; this must be soaped in advance on the side which the print is to be made, so that the colour does not come into direct contact with the paper.

The plate having been inked and covered with the paper is pressed between two felt cylinders. When the paper is of the required dryness, it is carefully removed from the plate, and turned over so that the printed side is upwards. This is put on to the article to be printed and pressed evenly by hand, and then with a pad, in such a way that every part of the transfer reaches the glass or ceramic ware. The article is then immersed in luke-warm water until the paper floats off.

Decoration by Means of a Spray

This process is used mainly for the decoration of earthenware, and consists of a spray which vaporises a liquid product containing colours. This spray can either be used to decorate complete surfaces or in conjunction with metal stencils.

Decoration with Metals

In addition to vitreous enamels, glass can be decorated with gold, silver or platinum. These metals allow a very much richer decoration than with other products.

Only metals which can be heated at a very high temperature can be used, where there is no fear of oxydisation. The decoration can be applied to glass in the form of a paste, usually by means of a brush; certain products can be applied by means of an engraved plate, or by the silk screen process.

Brilliant liquid gold consists essentially of gold resin dissolved in turpentine and oil of lavender. It is essential that it should contain a small proportion of thorium or bismuth which gives brilliancy to the gold so that it does not have to be rubbed up after baking. Solutions of brilliant gold, silver, or platinum are put on with a brush, in the same way as vitreous enamels.

Amber is generally a mixture of salts of silver and tin. During baking, the salts and ions of the silver or tin penetrate into the glass, replace the alkaline ions, resulting in a transparent amber colour.

By this process, it can be understood that the result will vary according to the nature of the glass, whether potash or soda, and also the degree of baking, which does not need to be very high, 450° being sufficient, but which must be prolonged. This pro-

cess is exactly similar to glass case-hardening, and it is for this reason that these products are sometimes called stains.

To obtain a ruby colour, salts of copper are used. The copper ions replace the alkaline ions, and give a ruby tint with the best effect.

Decoration by Transfers

Ceramic transfers are printed by the lithograph process. The design is entirely covered by a coat of varnish which prevents the ceramic colours from altering in any way, and enables the paper to have perfect contact with the article to be decorated. To avoid powdering, sometimes direct inks are used, but the results are not so good.

The advantage of transfers is that a multi-coloured decoration can be applied in one operation. The two principal disadvantages are:

Difficulty in obtaining sufficient deposit of colour in order to realise the exact shade of colour required.

Applying transfers to the article is both slow and difficult.

To remedy the first disadvantage, transfers are now being made by the screen process.

The Silk Screen Process

The methods of decoration of glass and ceramics described up to now can often be replaced by the screen process, which is the most rapid and economical way of printing with vitreous enamels directly on to the article. This is the ideal method for reproducing copper plate engravings, wood engravings, acid engravings, and in a general way, all line engravings.

The silk screen process consists of a stencil on a piece of stretched silk which has been blocked-out in all the parts where the design is not represented. If this silk screen is placed on a sheet of paper, and by means of a rubber squeegee, the ink is pressed through that part of the screen which is not blocked, a perfect print of the design will be obtained on the paper.

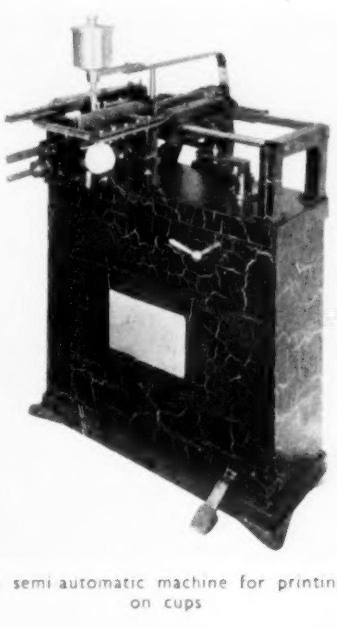
This process has the tremendous advantage of allowing a very thick coat of ink, as much, if not more, than by the very expensive copper engraving method.

The material which is almost universally used for silk screens is bolting cloth. This is very strong, and can be stretched considerably without losing its shape.

These silks are made up in three different ways: Full gauze, in which every thread has a double twist; half gauze, in which every other thread has a double twist; plain weave, in which the threads are as in ordinary material.

Nylon has been considered as a suitable material for making screens, as it is very much more resistant than silk. Unfortunately, it is very difficult to make nylon silk in the full-gauze weave, described above. It is, therefore, necessary to use plain weave, and to heat the strands slightly, so that they melt into one another and become absolutely fixed.

Metal screens can also be used. These are easier to stretch, are more solid in case of an accident, and have a stronger resistance to an alkaline reaction. If, however, they do get out of shape accidentally, it is very difficult to repair them. For this reason, many people have a preference for stainless steel, which is stronger and less likely to lose its shape.



A semi automatic machine for printing on cups

In printing glass and ceramics, the choice of the material of which the screen is made is very important, because on this choice depends the fineness of the work, the amount of ink deposited, and above all, the length of the life of the screen.

In a general way, metal screens of the same reference number give a thicker coat of ink than ordinary silks. This is because in metal gauze, the threads are very thin compared to the holes representing the stitches, whilst in ordinary silks, especially the fine reference numbers, the threads are even larger than the holes.

Under these circumstances, metal mesh will leave a deposit of little squares of ink very close to each other, which when joined up, give a thick coating of ink, whilst ordinary silks give a deposit of squares far away from each other, and which, when joining up, give a much thinner coating.

This is why very fine silk mesh should be used for gold decoration by the screen process. Ordinary silk is also used when printing on borosilicate glass (pyrex type). Great difficulty is experienced in getting the same degree of expansion in heat between the enamels and the glass, and for this reason very thin coats of enamel are used, which precludes the use of metal screens.

The frames on which the mesh is stretched are generally of wood, and their dimensions vary considerably. They should be solid enough not to lose their shape under the tension of the stretched silk. It is also possible to make frames with removable sides, so that the mesh can be regulated during working.

For certain processes, metal frames are much more suitable. Metal mesh is more easily stretched on these frames, and also the frame can be very narrow, so that a design can be printed right up to a cup handle, for example, which is not possible with a wooden frame.

Making the Screen

There are three principal methods of making the screens, that is to say, blocking out all that part not covered by the design: 1. Direct method. 2. By Cutting. 3. Photochemical method.

The direct method is very little used for ceramics, and consists of drawing directly on to the silk.

Cutting is also little used for ceramics. However, when printing on biscuit, it can be of interest.

This method consists of using special papers, opaque or transparent, which are covered with a film, either of cellulose acetate or gum-lac. Take the transparent paper, place it on the art-work to be reproduced, follow the outline of the drawing with a knife without cutting the backing paper. Then remove the cut pieces, which should represent the design to be printed. Then place the film on the mesh, and following the nature of the special paper used, fix the film to the screen, either by passing a hot iron over it, or with the use of a solvent which sticks the film on to the silk. The supporting paper can easily be removed.

If a very thick coat is needed, it is better to prepare the paper specially, as it is possible to choose anything from tracing paper to very thick paper, and the thickness of the coat of enamel depends directly on the thickness of the paper used.

Photochemical Method

This method has the advantage of speed, and perfect reproduction. It is based on the well-known property of gelatine, gum-lac, fish-glue, albumen, and polyvinyl alcohol, and in a general way, the majority of colloids, to react with potassium dichromate to become sensitive to light. To bring about this process, the following methods are used: Direct; indirect; use of gelatine film.

Direct photochemical method. A solution of the colloid with salts of chromium (sel de chrome) is prepared, exactly like that used by process engravers. This prepared solution is kept in darkness. It is either (the colloid) gelatine, glue, or polyvinyl alcohol dissolved in water, and to which has been added potassium dichromate. This solution is spread on the silk, which should then be left in darkness for the coating to dry. When it is dry it is placed in a photographer's press which has been specially constructed. Place the positive of the design to be reproduced in contact with the gelatine in the press, then expose to a strong light, the time of

exposure varying according to the strength of the dichromate, the distance of the light and its intensity.

The exposure completed, the screen is developed in luke-warm water if gelatine or glue have been used, and in cold water if polyvinyl alcohol has been used. Where the gelatine has been exposed to the light it will become insoluble, but where it has been protected, it will dissolve, thus freeing the stitches of the screen and exactly reproducing the design.

Indirect photochemical method. This is the same principle as above, but the work is done on paper instead of directly on to the screen. This paper, which is similar to the carbon paper used in gravure, is made in England by Autotype.

This paper is covered by a coat of dichromated gelatine, just before use; to do this, it is submerged in a solution (of gelatine) with 1 per cent. potassium dichromate. This is then left to dry before exposing under a positive. The paper is then wetted and applied firmly on to a sheet of celluloid.

The paper and celluloid is then dipped in warm water, to eliminate the remaining soluble gelatine. The paper being removed, an insoluble gelatine negative is left on the celluloid.

This is placed on a table with the gelatine facing upwards; the screen is placed over it and pressed on it with a clean cloth. It is allowed to dry; the gelatine will stick firmly to the silk, and the celluloid is easily removed.

By this method, finer screens can be made. Moreover, as by the cutting method, the design is stuck on to the silk, and perfectly straight lines can be obtained, as the stitches can be blocked out in bias, instead of a jagged line, as is the case with the direct method.

Gelatine sheet method. This is one of the best but most difficult methods. First, coat the silk with gelatine, let it dry and then stick on a sheet of gelatine in cold water. When dry, treat with dichromate, and dry again. Expose in the usual way and develop in warm water.

The positive is of very great importance to the final result. It must be highly contrasted to save trouble when developing. For this reason one makes use of printed Kodatrace (transparent paper), sheets of cellophane or Plexiglas. However, as the print rarely gives blacks which are sufficiently opaque, it is a good precaution to dust them with metallic powders. Positives made by the usual photographic processes are also used, but these should be always with very solid blacks.

Waterproofing of Stencils

When screens are to be used with water-based colours, it is necessary to protect them with resistant-to-water lacquers. This waterproofing is done in the following way: Coat one side with a varnish, then clear the stencil with an adequate solvent. When perfectly dry, coat the other side of the screen with another varnish, and then clear the stencil once more with the appropriate solvent. It is essential that the second varnish should be absolutely incompatible with the first.

When decorating on biscuit, glycerine-based colours are used. It is, therefore, necessary to make the screens waterproof, but as the enamels and the biscuit are both very abrasive, the waterproofed stencils which contain gelatine, have a very short life, because the gelatine always has a tendency to swell. In this case, it is advisable to make the screens by the cut-out method, or by any other method which does not use gelatine.

To make these special screens, use the negative and not the positive as previously, with for instance, the Autotype paper. Cover the screen with a fatty or cellulose lacquer; when dry, boil the screen in water, the gelatine will swell, will come off and take away with it the varnish, freeing at the same time the holes of the mesh corresponding to the drawing. In this way the screen will be entirely made with the lacquer and perfectly resistant to water.

(To be continued.)

Positive Ventilation. Under this title, Sturtevant Engineering Co., Southern House, Cannon Street, London, E.C.4, in publication No. 3702, superseding No. 3701, outline their contributions towards factory ventilation. The booklet is copiously illustrated with typical installations both of the static and portable type equipment.

METAL OXIDE REFRACTORIES.—*(Continued from page 112.)*

546, 387; 584, 626). This involved grinding and digestion with acid similar to the methods already described above.

Casting was carried out in plaster moulds with a slip containing at least 80 per cent. by weight of solids acidified to *p*H2, using small amounts of deflocculent if required. For extrusion a starch binder was used. Owing to the fact that zircon develops no plasticity on grinding the green strength of slip cast articles is low, and the extrusion technique (with a binder) is preferred. Firing was carried out at about 1,750° C. to avoid dissociation to zirconia which is known to occur around 1,800° C.

These authors have made determinations of the physical properties of extruded and slip cast zircon, and the original paper should be consulted for the values. They have shown that the material has good strength and elasticity modulus. The thermal stock properties are superior to those of alumina.

Fused Magnesia

Pure magnesium oxide does not melt below 2,800° C., but the presence of impurities lowers this value. To overcome volume changes due to hydration the electrically fused material is used for very high temperature work. The history of this development has been traced by H. E. White[illegible] who also reviews the properties of the various grades of magnesia. These are also reviewed by Burrows Moore[illegible]. W. H. Henson (loc. cit.) summarises the properties of fused magnesite as follow (94-96 per cent. MgO, 2-3 per cent. SiO_2, 1-2 per cent. CaO:

- P.C.E. (or fuse point)—3,992° F.-4,532° F.
- True sp. gravity—3·60.
- Approx. wt. of 9 in. brick—10 lb.
- Linear coeff. expansion/° C.—150×10^{-7} (20-1475° C.).
- Thermal conductivity (BTU/hr./sq. ft./in./° F.)—20 (2,000° F.).
- Mean spec. heat (c.g.s.)—0·292 (32-2,375° F.).

(Continued on page 128.)

MILLING AND MATERIALS

by

A. RILEY

THE materials dealt with in this lecture will be flint and stone. They are the main materials with which a miller has to deal. As far as flints are concerned, they are either beach flints or wash mill flints. Raw flints are very hard, but nevertheless, if a flint lies in contact with a piece of rusty iron for very long, it becomes stained, and in the same way, if the flints lie in dry red sand for a lengthy period, they will not fire as white on the outside as they should do. Beach flints should, therefore, be picked below high-water mark. A good type of beach flint is sucked up from underneath the water.

Wash mill flints are a by-product of the cement mills. They are dug out along with the chalk. The chalk is washed off in the wash mill, which is similar to a wash tub in a pan mill, and the flints are knocked about in the wash mill until all the chalk is removed, then fed into a washer to remove the cement-slurry. With the most modern plant they are then good pottery flints, while in the older type mills, the flints from the washer are graded by hand into first and second quality.

China stone comes from near St. Austell in Cornwall, and is usually classified in three grades, hard purple, mild purple and dry white. If the material has to be classified, it is not advisable to use any dry white and only about 50 per cent. of mild purple.

Calcining

China stone is ready for crushing and grinding when it leaves the quarry, while flints must be calcined. This is usually done in intermittent kilns, usually bottle shaped. Inside the outer shell of the kiln, there is a cylindrical steel casing, lined with common brick, except for just around the base where the fire is started, where firebricks are used. When filling the kiln, a fair amount of wood and coal is placed in first, then a quantity of flints are put in and usually levelled and fuel spread over, slightly more on the outside of the circle, and in the proportion of about ¾ cwt. of fuel to 1 ton of flints, this process being continued until the kiln is full. The wood and fuel at the bottom are then lighted, and the kiln allowed to burn through. When cool, the kiln is ready to be drawn. It is not essential to level the flints. If the kiln is filled by wagon, the amount of fuel per wagon can be calculated and spread over the wagon after it has been tipped. When the kiln is filled by tipping by lorry load (say 6 tons), the fuel should be sprinkled in as the lorry tips slowly. This type of kiln can be worked continuously if the kiln is drawn from the centre and filled from the centre. There is a continuous gas-fired kiln in operation, consisting of a long vertical tube with a firing zone in the centre, in which the raw flints are fed into the top, pass through the firing zone and are drawn out at the bottom. This type of kiln provides a better control.

Control of Firing.

The control of the firing is by regulating the amount of fuel. The flints should be calcined to a definite specific gravity, usually 2·50-2·52, which can be roughly assessed by the colour of the calcined flint. If it has been calcined to a dead white colour, the specific gravity is probably below 2·50. The test for specific gravity is better done from flint in the slop state, if dry flint is used, it is very

difficult to remove all trace of air bubbles. The method we generally use for specific gravity tests is to fill a specific gravity feed tube (as used in the Andrews Elutriator) with slop flint, and then swill this out into an evaporating basin, dry and weigh, the difference between the weight of the tube containing the slop flint and that of the tube full of water being the amount by which the flint is heavier than its own volume of water. This difference subtracted from the weight of the dry flint gives the weight of a volume of water equal to the volume of the flint. To find the specific gravity, the weight of the dry flint is divided by the weight of an equal volume of water. From the result of this test, the amount of fuel can be adjusted.

When the flints are drawn from the kiln, they can be separated from the coal ash by passing through or over a screen of [illegible] in. mesh.

Crushing

Before the flint or stone is ready for the fine grinding, it must be crushed. With china stone, a two-stage method must be employed. The stone is delivered in pieces up to 1 cwt. in weight, and should be fed to cylinder mill in pieces no bigger than [illegible] in.; a two-stage crushing is probably better for flints. It is easier to arrive at a finer product by making the final stage a closed circuit, any chance of oversize pieces being present in the feed to the mills is eliminated. To do this, the discharge from the final crusher can be passed over a sieve of a pre-determined size, and anything above that size, returned for further crushing. The size of the feed to the mill determines the size of pebble to be employed as grinders; the larger the pebble the less the cylinder will grind, and so it is obvious the finer the feed, the greater will be the output of the mill.

Viscosity

When the material has been finely crushed, it is ready for the final stage of grinding, for pottery purposes, a wet process. When the flint is mixed with water, the viscosity of the mixtures becomes of importance, mainly depending on the pint weight of the mixture. The viscosity is also affected by the state of flocculation or dispersion. If soda is added to slop flint, it can be poured quite easily from a jug at 34 oz. to the pint. If calcium chloride is added, it is almost impossible to pour at 34 oz.

During the grinding process runners or pebbles (depending on the type of grinding) must move through the mixture, therefore, it follows that it is better to keep the mixture as mobile as possible. There is also another consideration. In order to do any grinding, all particles must be easily accessible, which is the case if the flint is dispersed, but when the flint, in a state of dispersion, is allowed to settle for very long, it will "set". This means that it would be quite impossible to move it again except by digging it out. Therefore, if soda ash is used for the grinding process, calcium chloride must be added to prevent the flint from setting during the thickening process.

The viscosity of the flint water mixture is also varied by the amount of fines present, which can be seen easily in pan grinding. During the first hour of the grinding, the pieces of flint can be seen to move quite easily in the mixture. If the pint weight at the end of the grind is adjusted to the same value as it was in the first hour, the difference in mobility will be obvious. This is one reason why more grinding takes place in the first hour of the batch grind than in the last hour.

Control of Grinding

In order to control the fine grinding, some method of testing must be adopted, the essentials of which should be speed and accuracy. Speed is put first because in the control of the grinding the quicker the result of the testing is known, the sooner any steps can be taken to correct the grinding. The method usually employed is either elutriation or sedimentation, depending on circumstances. If the operator can give his whole attention to the testing, and not have to, say, answer the phone, sedimentation is better and quicker, as a complete result can be arrived at in about 20 min.; with elutriation it would probably take twice as long.

In sedimentation there are several points to watch.

1. The sample must be properly dispersed, i.e., it will not flow across the bottom of the cylinder when the test is complete.
2. The same timing must be used only for samples of approximately the same material of the same fineness.
3. The temperature of the room must be as close as possible to the temperature of sedimentation.

Elutriation does not need such close attention, but nevertheless, there are certain points to note.

1. Always use about the same weight of sample for elutriation in the same time.
2. Whenever possible, adjust the velocity to suit the temperature of elutriation.

This latter is very essential for summer and winter temperatures may vary by as much as 30° F. Since for a normal pottery slop flint the result varies by ·28 per cent. for every 1° rise and fall in temperature, this may mean a difference of 30 × ·28 = 7·4 per cent.

The velocity for any value of the given temperature is easily arrived at by taking the viscosity of the water at the required temperature. If we assume a standard temperature of 60° F. (value of water viscosity ·01126), and require to elutriate at 65° F. (viscosity ·01050) a sample proportion gives the required velocity.

If the standard velocity at 60° F. is one pint of water in 160 sec., at 65° F. this time must be reduced to:

$$\frac{160 \times 1{,}050}{1{,}126} = 149 \text{ sec.}$$

A table of velocities worked out in this manner will give complete control of the temperature variation. By the use of an Andrew Elutriator, an estimate can be obtained in about 1½ hours by turning off the water supply and allowing the residue to settle into a graduated bottom vessel. A reading from this will give a fairly accurate approximation of the final result.

Some manufacturers require a given plus ·02 content, while others rely on a minus ·01 content. The miller should, therefore, take out two fractions in the test. In the case of sedimentation, this means two readings at different time intervals, while in elutriation, to obtain a second fraction, the overflow from the Andrews can be turned through a second vessel giving a slow rising velocity.

The sampling of the product is much better done from a wet sample, as if a dry sample is used, it is very difficult to remove all air bubbles.

Methods of Grinding

There are three methods now in use in the potteries for the fine grinding of flint and stone. The oldest and most expensive method is pan grinding. The other two methods are both cylinder grinding. The most common is by batch grinding. Hardinge cylinders are used to a lesser extent. Pan grinding and Hardinge cylinders have one thing in common, namely, the product is taken off partly ground and the finished result obtained by classification. Batch cylinders grind to finality, i.e., all the product is finished product.

The principle employed in pan grinding is to grind the material between the heavy runners and the pavers in the bottom of the pan, and this depends on two main factors.

1. The state of the runners and pavers.
2. The viscosity of the material.

When the pan is newly paved or freshly runnered, it tends to produce more fines. If the material is tested by taking out plus ·02 and minus ·01 plus ·01 this can be seen by noting the ratio of the minus ·02 plus ·01 to the minus ·01 fraction. For instance, a freshly paved pan might produce a sample 40 per cent. plus ·02, 15 per cent. minus ·02 plus ·01, 45 per cent. minus ·01.

$$\frac{\text{Minus ·01}}{\text{Minus ·02 plus ·01}} = 3$$

while a pan which has not been runnered for some time might give 40 plus ·02, 20 per cent. minus ·02 plus ·01, 40 per cent. minus ·01.

$$\frac{\text{Minus ·01}}{\text{Minus ·02 plus ·01}} = 2$$

The viscosity will affect the grinding in much the same way, and the more mobile the mixture, the higher the above ratio.

Viscosity of the charge is directly affected by the speed of the pan: the slower the pan the lower the pint weight which can be used; the faster the pan the higher the pint weight used to prevent the material being swilled out of the pan. The faster pan does not grind any more.

The grinding time necessary to produce a given result depends on the amount of the charge, other things being equal. The power taken measured in Kilowatts depends on the fineness of the product required, but is almost double that taken by a Hardinge mill.

Cylinder Milling

The principle of pan grinding is different from that of cylinder milling, in that by the motion of the stones, all the material must pass underneath them. In cylinders in order to be ground the material must cling to the surface of the pebble in order to be ground by rubbing against other pebbles. This means that the viscosity of the mixture must be sufficient for it to adhere to the pebbles, but not so high as to prevent movement of pebbles. The best pint weight for cylinder grinding depends on the state of flocculation or dispersion of the mixture.

For batch grinding, there are various factors which must be noted.

1. The amount of pebbles.
2. The weight of charge.
3. The amount of water.
4. The speed of the cylinder.

The first three are dependent on the carefulness of the men in charge, and are difficult to check when the cylinder has been charged.

The size of the pebbles is determined by the size of the feed; the smaller the feed, the smaller the pebble which can be used; the smaller the pebble the greater the surface in which the grinding can take place and therefore, the more grinding that does take place. The disadvantages of the batch against the Hardinge are:

1. Greater room needed for the same output.
2. Not easily controlled from the laboratory.
3. Slightly more power taken.

The advantage is that a small output is more convenient and definitely more flexible.

Hardinge Milling

Hardinge milling is continuous cylinder milling and similar conditions should prevail. One of the advantages of Hardinge milling is that the conditions inside the cylinder can be seen and if wrong, corrected. The feed to the Hardinge is automatic. We have found the best feeder to be the Hardinge Constant Weight Feeder, which, as the name implies, is designed to give a constant weight. If the feed is too great, a valve controlling the feed is closed slightly, and if too small, the valve is opened. Vibrating feeders are not so reliable because they are affected by the amount of fines in the feed and also its moisture content. The discharge from the Hardinge is pumped through a classifier which returns the oversize to the mill and the finished product to the thickener.

Material from Pan or Hardinge

To show the value of classification and the effect of pint weight a series of tests were run on a pan at different pint weights and with different amounts in the pan. Samples were taken off every hour, and the watt hour meter read. Each sample was tested for plus ·02 and plus ·01. By taking the amount of minus ·01 produced, the units per ton were calculated for each sample. If, say, 24 per cent. minus ·01 was produced and the standard was 60 per cent. minus ·01 this 24 per cent. minus ·01 would require $\frac{2}{3} \times 24 = 16$ of plus ·01 to bring the sample up to standard, i.e., $16 + 24 = 40$ per cent. of the grind would be finished product, and since the k.w. used was known, the units per ton could be calculated. Also since all the minus ·02 fraction would be finished product, the grading of the finished product would be known. This gave some very interesting results. Taking the two tests run at 35 oz.

	Units per ton	*Plus ·01 minus ·02 fraction*
The 4-hour charge for the first hour gave	130	26
The 4-hour charge for the second hour gave	157	24·5
The 4-hour charge for the third hour gave	186	22·4
The 4-hour charge for the fourth hour gave	199	21·0
The 8-hour charge for the first hour gave	98	27·3
The 8-hour charge for the second hour gave	116	27
The 8-hour charge for the third hour gave	130	26
The 8-hour charge for the fourth hour gave	140	24·5
The 8-hour charge for the fifth hour gave	154	23
The 8-hour charge for the sixth hour gave	174	20·5
The 8-hour charge for the seventh hour gave	190	19·8
The 8-hour charge for the eighth hour gave	200	18·9

This shows that the longer the material stays in the pan, the higher the units per ton, and at this pint weight the longer the material is in the pan, the finer the grinding. These figures are taken off a pan and do not necessarily apply to cylinder grinding as far as the grinding is concerned.

Taking another two samples run at 37 oz. to the pint the following results were obtained.

	Units per ton	*Plus ·01 minus ·02 fraction*
The 4-hour charge for the first hour gave	130	26
The 4-hour charge for the second hour gave	164	29·8
The 4-hour charge for the third hour gave	192	26
The 4-hour charge for the fourth hour gave	201	26
The 8-hour charge for the first hour gave	97	30·6
The 8-hour charge for the second hour gave	106	29·4
The 8-hour charge for the third hour gave	130	29
The 8-hour charge for the fourth hour gave	148	29
The 8-hour charge for the fifth hour gave	169	27·8
The 8-hour charge for the sixth hour gave	167	28·3
The 8-hour charge for the seventh hour gave	177	30·3
The 8-hour charge for the eighth hour gave	190	29·6

This shows again that the longer the material stays on the pan the higher the units per ton.

At this pint weight the grading does not change to any great extent; and is rougher than the grinding at 35 oz. to the pint.

These results show that the material should come off the pan quickly. We are limited in this respect by the capacity of the classifier. It is quite easy to draw off the finished product, but quite another matter to take away the oversize. If this oversize is not taken away in the correct proportion it will obviously build up and finally come over with the finished product. The ground material must, therefore, be fed into the classifier at such a plus 02 content that the classifier can return for regrinding the correct proportion of fines. It is desirable to test the mill product to ensure that this condition is satisfied.

Classifiers

The classifier usually associated with pan mills consists of a large tank fitted with agitators called wash tubs. The material from the pans is run into this and diluted with water to about 23 oz. to the pint. The agitators are then stopped and the material allowed to settle. When a lawn test shows it is ready, the material is run into settling arks from a series of sluice valves fixed in the side of the wash tub one above the other.

Apart from wash tubs, there are two main types of classifiers in use at the present time: one which is closed at the top and the finished material syphoned out, and the other with an open top in which the finished material runs over the top rim. We will deal with the syphon type first.

In order to control rising velocity in the classifier we must have a steady head on the feed pipe, which is provided by a governor tank, consisting of a tank into which the mill feed, diluted with water, is pumped. The excess material runs over the edge of the tank and is returned to the pump, the pump being designed to give a reasonable overflow to ensure that the governor tank is always full. The feed to the classifier is either sucked out of this tank over the top, or from a point below the top, depending on the design of the classifier. A steady feed is thus ensured for the feed. The feed passes through the outer wall of the classifier and is directed into a circular fitting in the centre tangentially to give a slight circular motion in the bottom of the classifier.

This fitting has a cover over the top to prevent disturbance in the top portion of the classifier. While the particles are kept in motion they tend to separate out more easily, the oversize particles falling by gravity to the opening at the bottom. Here we can have two types of spigot opening. One is an ordinary full-way gland tap slotted to provide a square opening when the valve is only just open, and the other a 6 in. to 8 in. sluice valve which is drowned under water in a draining wheel.

The full-way gland tap type is simple, but will only deliver the oversize at a maximum pint weight of about 31 oz. The syphon on the overflow relieves the pressure on the spigot valve and enables it to be opened fairly wide without any large flow from the spigot.

In the sluice valve type the valve is fully open and the oversize drops through into the draining wheel. It settles in this wheel and is delivered through the centre of the wheel back to the mill at approximately 34 oz. to the pint.

In order to control the syphon, the end of the pipe is drowned in a long tube with a valve at the bottom. By regulating this valve the water head in the control tank is varied. Also, the classifier can be made either to flow into or suck out of the draining wheel, varying the rising velocity in the classifier. A drop-feed taken continuously from the syphon leg provides a true sample of the finished product.

There will be thus two tests for control purposes, one from the mill and one from the classifier. If any fault develops it can be ascertained whether the mill or the classifier needs attention.

The overflow from the classifier will be very dilute, about 21 oz. or 22 oz. to the pint, and in order to prepare this for use, most of the water must be removed by running it into an ark. When that material has settled out, the water can be run off through suitably arranged holes in the end of the ark.

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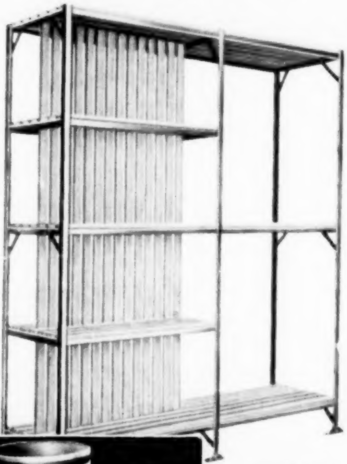

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The open-top type classifier is very similar in shape to the top vessel of an Andrews Elutriator, and as with the syphon type of classifier, the mill feed is maintained at a steady head. The feed is discharged at a point about one-third of the way down. Situated around the bottom conical section are pipes which introduce a supply of water which washes the settling oversize and can be varied if it is found necessary to adjust the upward velocity. The oversize accumulates in the bottom until it is discharged through a valve, the operation of which is controlled by a system of cams and rollers.

Hardinge mills are usually produced with thickeners, which are merely continuous arks, the dilute material being fed down a tube in the centre of a circular tank. This tube goes part way down the tank. The water flows down underneath the bottom of this tube, then rises into the main tank and away over the edge. This tank is of sufficient diameter to prevent the rising velocity being high enough to carry away any solids. The liquid in the thickener is given a slight circular motion to prevent any short circuiting of the flow.

If the storage arks are fairly long they can be used in pairs as thickeners. The overflow from the classifier is fed into one end of the ark—flows down the ark and over a weir into the next ark. The top running-off plug is left out in this ark, which thus serves as a trap for any solids which may be washed over. As soon as any solids start to pass over the weir the overflow from the classifier should be directed into another ark.

METAL OXIDE REFRACTORIES.—(*Continued from page* 119.)

- Deformation under load—poor load bearing above 2,732° F.
- Shrinkage—less than 1 per cent. below 3,250° F.

This means that the thermal expansion is high, but so is the thermal conductivity, thus reducing the effect of thermal shock. The hardness is 6 on Moh's scale. The sources of magnesite have been described in an article, "Magnesite Refractories" in the June, 1952 issue of CERAMICS.

Fused magnesia is stable in the presence of carbon up to 1,800° C. It is also resistant to basic slags. Up to this temperature it shows little tendency to vaporise. The electrical resistivity is high. Shaping can be done by the methods previously outlined.

Swanger and Caldwell (loc. cit.) give directions for tamping articles using fused or sintered magnesium oxide ground to pass a 60's mesh, mixed with 2 per cent. of magnesium chloride ($MgCl_2 \cdot 6H_2O$) as a binder in the minimum amount of water. Graphite or pasteboard moulds can be used and the articles fired in them since there is no reduction of the oxide up to 1,800° C.

Fused magnesia is used in crucibles for melting the precious metals, for furnaces for very high temperatures, and as a bedding material for electric hot plates.

Thoria ThO

This material has the highest melting point of the refractory oxides (approx. 3,000° C.). Its cost, however has so far restricted its use to the preparation of crucibles for melting the precious metals.

Details of the method used at the U.S. National Bureau of Standards for making thoria crucibles are given by Swanger and Caldwell (loc. cit.). Briefly the method involves fusing the thoria in a carbon arc, and then milling and extracting with acid as described for the other oxides. A solution of thorium chloride in water is used as the bonding agent and the shapes are pressed or tamped, and after drying are fired at 1,800° C.

The physical properties of thoria are given (1) as:

- Sp. gravity (gm./cc)—9·2.
- Compressive strength (p.s.i.)—220,000.
- Transverse strength (p.s.i)—17,900.
- Mod. of elasticity (p.s.i)—1·79 × 10.
- Moh's hardness—7.
- Coeff. thermal expansion × 10—
  - 8·5 (100-500° C.).
  - 9·2 (500-1,000° C.).
- Thermal shock resistance—Fair.

Calcium Oxide CaO

This oxide has a melting point of 2,570° C. and is a cheap raw material freely available. It is however, subject to hydration with expansion, and has not hitherto attracted any attention as a refractory apart from the use of calcined dolomite ($CaCO_3$, $MgCO_3$) in metallurgical furnaces. Could the oxide be stabilised it would be of inestimable benefit to industry. This has not yet been achieved. Small crucibles have been made in laboratories for immediate use in metallurgical operations.

A. E. Williams[18] has described methods of preparing lime articles with a higher bulk density than normal, and has shown that this slows the rate of hydration. The fired articles can be protected by coating with an emulsion of polyvinyl chloride in tri-cresyl phosphate.

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Depreciation and Maintenance of Pottery Manufacturing Equipment

2.—"Straightline" Method as applied to Kilns and Furnaces

by S. HOWARD WITHEY, F.Comm.A., etc.

ALTHOUGH some kilns are more economical than others and ensure a greater degree of heat recovery and application to ancillary processes, as well as a more scientific utilisation of fuel, the first or original capital cost should be spread over the period of service, or useful life, as evenly as possible, after making allowance for their estimated value at the end of that time, and while depreciation computations are often complicated by reason of wide variations in the useful life of capital additions, the nature of the annual loss does not change, and instead of providing a round sum to cover wear and tear and other deteriorating factors, it is advisable to determine the amounts to be written off each year in accordance with a definite scale and to incorporate these figures in the manufacturing costs.

The use of refractories and protective coatings can do much to stabilise the cost of repairs and renewals, and enable a fixed amount to be charged each year for depreciation and maintenance, and many pottery manufacturers are able to apply the "straightline" method of computing and recording the inevitable decline in the capital value of kilns and furnaces. In a recent case, for example, the difference between the book value of such assets and the estimated residual value at the end of another six years, is being allocated over the period in the form of equal annual instalments, and it is not expected that the cost of repairs, cleaning, overhauling and adjusting will vary materially as between one operating period and another. At the end of December, 1951, the Kilns and Furnaces Account kept in this manufacturer's private ledger showed a balance of £12,000, and at a conference of engineers and executives it was agreed that the value would be no more than half this amount in 1957. In January, 1952, additional electric arc furnaces and groups of silicon carbide kiln furniture were acquired and installed at a total cost of £8,500, including the carriage charges, installation expenses and certain foundation charges, and this amount was recorded in the "capital outlay" column of the purchases journal and transferred at the end of the month to the debit side of the asset account. It was decided to spread the whole of this new capital outlay over a period of ten years; consequently, the computation of the annual depreciation charge for costing purposes was made as Table 1.

In order to facilitate the compilation of the various asset accounts, it is advisable to use a pattern of purchases journal which has been provided with a sufficient number of columns to enable the items of capital expenditure to be grouped for transfer to the ledger. The classified headings will naturally vary according to the kind of products, the varieties of clay and the specific processes, and instead of a bound ledger of the ordinary type some manufacturers prefer to use cards of convenient and uniform size —such as 6 in. by 4 in.—which can be kept in a cabinet or drawer and maintained in position by means of a steel rod or other similar device. At the top of each card sufficient space should be reserved for a description of the equipment, its exact location, the name of the maker or supplier,

TABLE I

One-sixth of £6,000 (viz., £12,000 *less* £6,000)	1,000
One-tenth of £8,500	850
Depreciation	£1,850

At the end of 1957 the private ledger account will show the following figures:

KILNS AND FURNACES

Debit					*Credit*
		£			£
1952			1952		
Jan.	To Balance brought down	12,000	Dec.	By Depreciation written off	1,850
„	To Additions	8,500	„	By Balance carried down ...	18,650
		£20,500			£20,500
1953			1953		
Jan.	To Balance brought down	18,650	Dec.	By Depreciation written off	1,850
			„	By Balance carried down ...	16,800
		£18,650			£18,650
1954			1954		
Jan.	To Balance brought down	16,800	Dec.	By Depreciation written off	1,850
			„	By Balance carried down ...	14,950
		£16,800			£16,800
1955			1955		
Jan.	To Balance brought down	14,950	Dec.	By Depreciation written off	1,850
			„	By Balance carried down ...	13,100
		£14,950			£14,950
1956			1956		
Jan.	To Balance brought down	13,100	Dec.	By Depreciation written off	1,850
			„	By Balance carried down ...	11,250
		£13,100			£13,100
1957			1957		
Jan.	To Balance brought down	11,250	Dec.	By Depreciation written off	1,850
			„	By Balance carried down ...	9,400
		£11,250			£11,250
1958					
Jan.	To Balance brought down	9,400			

etc., and in addition to these records an inventory of the entire layout should be kept, this being preferably divided into sections to correspond with the varying types, specifications and capacities. Each entry made in the inventory should give the date as shown on the original invoice or other debiting document, the name of the constructor and a sufficiently detailed description to enable the particular equipment to be readily identified. In addition to proving of considerable utility to the management and staff, such information enables a proper distinction to be drawn between the expenditure to be capitalised and the expenditure to be charged against profits.

When drawing up a balance sheet exhibiting a true and correct view of the financial position, it is a matter of prime importance that capital expenditure should be clearly distinguished, and the principles upon which a discrimination between balance sheet items and profit and loss items should be based can, perhaps, best be indicated by referring to an actual case.

Recently an old-established pottery

manufacturing business was taken over by a company as a going concern, with the shops, decorating department, slip house machinery, packing house equipment, pottery stocks and work in process, all of which were treated in the company's books as capital outlay. Additional machines were then acquired, the net cost prices being posted direct from the cash book to the debit side of appropriate ledger accounts, and as at 30th June the accounts were balanced and audited. Owing to damage, some of the physical assets had to be subjected to a revaluation on the part of an acknowledged trade expert, and the difference between the book value and the new valuation figure was written off against the revenue, in addition, of course, to an adequate sum to cover the decline in the capital value of the other productive equipment. The payment made for the goodwill of the old business was regarded as a capital charge, but the intangible nature of this asset rendered it a somewhat troublesome item to deal with in the final accounts, and eventually it was decided to show the original cost price on the balance sheet and to deduct from this amount a proportion allocated towards extinguishing the item altogether, this deduction being debited to profit and loss. The cost of acquiring additional buildings was treated as a capital charge, as also were the legal expenses which were incurred in the transfer of the property, and as it was found necessary to undertake repairs in order that the clayworking machinery should attain its true value, the total cost of these repairs was transferred to the debit side of the private ledger account. All future repairs and maintenance charges, however, will be debited to profit and loss unless, of course, the outlay has the effect of increasing the value of specific units or groups of equipment as between a willing buyer and a willing seller. Certain carriage and transportation charges incurred in the acquisition of laboratory plant were debited to the asset account on the principle that

(*Continued on page* 142.)

Castable Refractories in Electric Furnace Manufacture

by

T. D. ROBSON

INCREASING interest has been shown during recent years in the applications of castable refractories (refractory concretes and mortars) to problems in the design of electric furnaces, electric heaters, etc. Such castables consist essentially of a refractory aggregate or grog, crushed to a suitable size and grading, and a hydraulic cement of the aluminous or high-alumina type which is available in Britain under the names "Ciment Fondu" and "Lightning." Mortars or concrete mixes made with these cements and a refractory grog are gauged with water to a plastic consistuency and tamped into any desired mould or shape. The mixes set in the cold after 2-3 hours and rapidly develop a very high strength so that they are ready for their refractory use in 24 hours (or earlier in cases of emergency).

Pre-firing before putting into service is unnecessary, and since the firing shrinkage is negligible, the furnace manufacturers can cast any shape with the knowledge that, at the operating temperature, it will have the same dimensions it had when cast.

One attractive application in electric furnace construction is the casting of holders or supports for resistance wire elements. These units are often quite complicated in shape with variously-designed grooves or slots to hold the heating coils and strips, but their construction in refractory concrete by direct casting is usually very simple. The design of the necessary mould will naturally depend on the type of resistance-element holder required, but an example of the many possible procedures can be illustrated. For this we have taken a modest unit suitable for laboratory furnaces or small glazing kilns, but analogous castings may, of course, be made in much larger sizes. Fig. 1 shows the completed refractory concrete holder with the resistance coils wound and placed in the slots. Fig. 2 shows the mould which consists of a base plate, a frame with detachable sides, and steel rods providing for the slots which will ultimately support the resistance wire. The rods rest on little wooden ridges (or beadings) which are fixed to the base plate in order to give the shape of slot required in this case. These rods are lightly greased before placing in the mould.

For a small unit such as this, where the distance between slots is not great, a suitable mix consists of a mortar made from four volumes crushed firebrick ([illegible] in. to dust) and one volume "Ciment Fondu" or "Lightning."

Since the grog is absorbent it is preferable to soak it in cold tap-water, allow it to drain, and thoroughly mix it with the cement, adding a little more water (if necessary) to bring the mix to the required consistency. The mortar should not be too "sloppy" but only sufficiently wet to ensure that it can be thoroughly compacted in the mould by vibration or by tamping. An hour or two after the mould has been filled the cement will start to set and the rods may be turned occasionally to prevent adhesion. The top of the unit should be given a final trowelling at the stage when firm pressure with a steel float is necessary to "bring up" any cement paste. The appearance of a very wet surface under the trowel shows that this operation is being carried out too soon. Shortly after the final trowelling, the rods may be removed for re-use. For highest strength and durability

the castings should be kept cool and wet for 24 hours (e.g. by covering with saturated clean sacking).

Crushed firebrick with a larger maximum size can be used for industrial units and suitable mixes are:

Mix A.

3 c. ft. crushed firebrick ([illegible] in. to [illegible] in.).
2 c. ft. crushed firebrick ([illegible] in. to dust).
1 c. ft. Ciment Fondu or Lightning.

Mix B.

2 c. ft. crushed firebrick ([illegible] in. to [illegible] in.).
2 c. ft. crushed firebrick ([illegible] in. to dust).
1 c. ft. Ciment Fondu or Lightning.

Refractory concrete resistance holders made in the above way are used with extremely good results in furnaces operating up to 1,200° C. Sometimes wash coats of P.B. Sillimanite cements Nos. 121 A and 120 E are applied to the face of the units before putting into service. This may help to prolong the wire life when operating at higher temperatures.

It is normal practice to place the resistance wires in slots or grooves rather than embedding them completely in the concrete. The latter technique should probably not be used for high temperature work but is permissible for some applications such as low temperature heaters, etc.

The electrical resistivity of refractory concrete is higher than that of the firebrick from which it is made as the following comparative tests show:

	Specific Resistivities in megohms per cm.^{3}			
	500° C.	700° C.	900° C.	1,000° C.
Firebrick	5	1	0·2	0·05
Refractory concrete	16	3	0·25	0·10

The bulk density of refractory concrete is about 110-120 lb. c. ft. (when in use) compared with 130 lb. c. ft. for firebrick. Because of the lower density of the concrete it has a marked insulating effect when replacing an

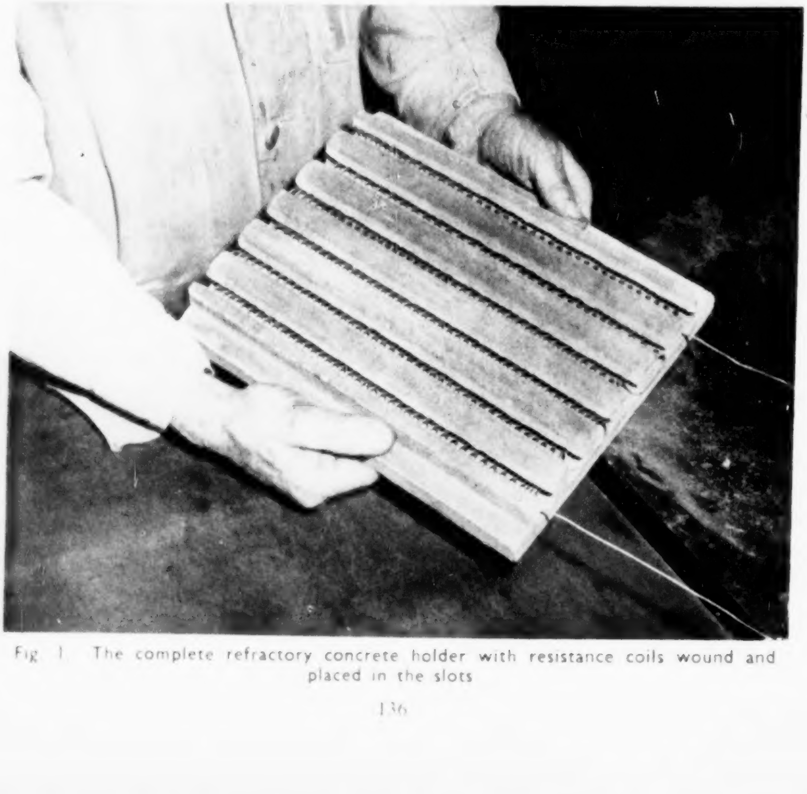

Fig. 1. The complete refractory concrete holder with resistance coils wound and placed in the slots

equal thickness of firebrick. In fact the average co-efficient of thermal conductivity of refractory concrete is about 7·5 B.Th.U./ft.^{2}/hr./°F./in., while that of firebrick is about 10 B.Th.U./ft.^{2}/hr./°F./in. over the same range of temperature.

For some parts of electric furnaces the maximum thermal insulation is required and a castable mix may also be utilised for this purpose. A mixture of lightweight aggregates, such as calcined diatomite or vermiculite, with aluminous cement gives "insulating concretes" which, like refractory concrete, can be cast to any desired shape. These insulating concretes are much lighter than refractory concrete. They are therefore not so strong and, in general, have a lower hot-face temperature limit of about 1,000° C. (with special aggregate this may be increased to 1,350° C.). The mechanical strength and density of the concrete depends chiefly on the proportion of cement present, but with a mix consisting of four volumes lightweight aggregate to one volume "Ciment Fondu" or "Lightning," the resultant concretes have thermal conductivities of 1·5 to 2·5 B.Th.U./ft.^{2}/hr./°F./in. while retaining a good degree of robustness. The bulk density ranges from 30-60 lb./c. ft. Lower proportions of cement give still lighter weights and enhanced insulating values at the expense of strength.

It is, of course, possible, and often very advantageous, to cast a composite unit with the hot-face consisting of refractory concrete and the remainder composed of insulating concrete. For this technique one type of mix is tamped into the mould to the requisite depth and is directly followed by the other type. The two kinds of concrete will harden together and remain throughout their working life without separation. This construction is particularly useful for furnace doors, hearths, walls and roofs, but it has also been very successfully employed for the resistance-element holders.

Both refractory concrete and insulating concrete have been extensively applied in industrial furnaces, e.g. for cover slabs and flat arch blocks in electric lehrs, and in continuous conveyor or truck-type annealing, enamelling, or pottery kilns. Complete car

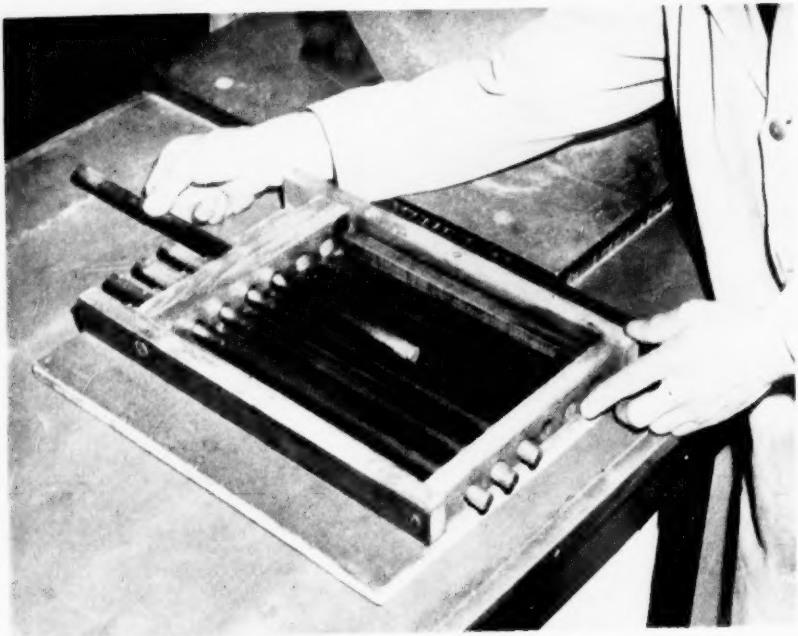

Fig. 2. Assembling the mould. The steel rods are slightly greased to prevent adhesion to the mortar

tops can be cast in refractory concrete and, when required, the lower layer may consist of insulating concrete.

In America, refractory concrete has been used to solve a difficult problem in the construction of tilting induction furnaces for melting alloy steels. These furnaces had a refractory brick lining in contact with the molten metal, but the exterior shell was a very complicated shape containing closely-spaced steel rods. The difficulty was successfully surmounted by casting a monolithic shell in refractory concrete.

A similar type of construction was used in electric-arc phosphate reduction furnaces for which very large monolithic refractory concrete domes weighing 120 tons were cast in situ.

Sometimes the advantages of castable mixes are required in situations where the hot-face temperature is above 1,350° C. In these cases a mixture of aluminous cement and a higher refractory aggregate such as sillimanite, fused alumina (corundum) and carborundum may be used. Thus a mix of six parts by weight of crushed sillimanite (¼ in. to dust) to one part by weight of aluminous cement, gave very good results in the cover of an arc furnace operating up to 1,450° C, while a mix with fused alumina aggregate has been satisfactory for casting sheaths in high-temperature electric resistance furnaces (carbon granule type).

WATER COOLING

UNDER the above heading, the Visco Engineering Co. Ltd., Stafford Road, Croydon, have published a booklet dealing with the Visco approach to water cooling. It is similar to the first edition published in 1947 but has been revised to include typical concrete and steel shell coolers installed during the last few years. In addition, there are a number of pages of meteorological information, together with a range of useful tables of interest to the practical engineer.

The booklet is comprehensively illustrated and gives specification details of different types of cooler available.

THE PRODUCTION AND DISTRIBUTION OF STEAM

with Special Reference to the Ceramic Industry

AN abstract of this paper, presented by Mr. E. Griffiths, appears in the *Transactions of the British Ceramic Society*, Vol. 51, No. 8, August, 1952, pp. 409-422—Discussion pp. 423-427, as follows:

The reasons why the use of steam is favoured in industry, particularly as a heating medium, are referred to, and the types of boilers in use, their relative efficiencies and characteristics, are mentioned. Attention is drawn to the advantages of auxiliary equipment such as fans for draught, mechanical stokers, economisers and mechanisation on the firing floor—for example, coal elevators. An example shows how an economiser increased the overall efficiency of a boiler plant and made it possible for the boiler to carry a 20 per cent. overload pending the installation of an additional boiler. In a section on smoke abatement, an effective smoke eliminator door is described. Two case histories exemplify boiler plant improvements; tables show capital expenditure for a new boiler plant and equipment, and the savings in fuel expected. A third case history exemplifies inefficient production and utilisation of steam, and improvements are advocated. It is suggested that, on any works, the first step towards improving steam utilisation is to draw up a steam flow diagram to show how the steam and its cost are apportioned among the various factory needs. Reference is also made to the combined power and process heat system as a means of producing cheap power.

Main Source of Heat

In his introduction the author says:

On the majority of factories in the ceramic industry, steam is at present the main source of heat for processing and also for the production of power. There are a number of good reasons why it is so widely used:

(1) Steam can generate power, and then be used for heating.

(2) It gives up its latent heat at constant temperature.

(3) It can be readily distributed and easily controlled.

On factories having a steam demand for process of, say, 4,000 lb./hr., and a power demand at least equivalent to approximately this quantity of steam to an engine, there is often a good case for investigating the advantages of using the steam first of all to produce power, and then to use the exhaust steam for the process. If the process steam demand is less than 4,000 lb./hr., it may be simpler to produce low-pressure steam for process only and to purchase electricity from the public supply.

High Efficiency

The use of steam instead of electricity, for example, for process and for comfort heating, even when not available as exhaust, is popular because of the high efficiency of generation that is possible. Under average conditions, a hand-fired steam-raising plant without an economiser or superheater should have an efficiency of, say, 60 to 65 per cent.; with an economiser (and superheater if the steam is used for the production of power) 70 to 75 per cent. efficiency is practicable. Therefore without the heat left in the condensate being considered—and it can always be put to some useful purpose—a boiler operating at, say, 5 lb./sq. in. (gauge) steam pressure has available as latent heat 80 per cent. of its total heat, so that if the efficiency of the steam-raising plant is only 65 per cent., we have a heating medium for comfort and

process work at a final efficiency of 52 per cent.

In recent years many manufacturers of ceramics have been giving thought to the advisability of installing new boilers, either because their present ones are old or because the steam demand has increased on account of factory extensions. When discussing types of boiler plant with manufacturers, we find that they are particularly interested in installing plant which raises the level of boiler-house practice above that prevalent in the past.

The extent to which auxiliary equipment on a boiler affects the general economy of a factory is sometimes not fully realised. It is likely, however, that the effect of such items of equipment upon the quantity and quality of the output of ware from the factory may exceed the value of the economies that are due to fuel savings only.

Efficient Utilisation

There is no virtue in steam being generated efficiently unless it is utilised efficiently also. The first step towards efficient utilisation is to draw up a diagram showing the quantity of steam, and its heat content, required for the various uses and for different sections of the works. A portable steam meter and some steam tables are necessary, and the points in the steam lines where the pilot head or orifice plate is fixed should be carefully planned. After some readings of steam flow have been obtained, others can be deduced by difference and inference. Even if this only gives the trend of the steam supply and how it is apportioned, such a picture will be advantageous.

Smoke abatement is very much in the news again. Excessive smoke emission from boiler stacks is mainly due to neglect during stoking, and results in injury to health and buildings, and fuel waste. Smoke can be reduced to some extent without the aid of any equipment, irrespective of the type of coal being burned, and with special equipment or mechanical stokers, smoke emission can be further reduced.

Mr. Griffiths then continues:

The boilers generally in use throughout the ceramic industry are the shell type, i.e., Lancashire, Economic, and Cornish, the few exceptions being water-tube boilers. There are also some vertical ones and, strange as it may seem, there are still a few egg-ended boilers "doing their best."

Lancashire and Cornish boilers are reliable, they steam with the minimum amount of trouble, and a Lancashire boiler with an economiser can be reasonably efficient. In the ceramic industry, economisers are not usually fitted to Cornish boilers; but, in proportion, they could effect the same economies as when fitted to Lancashire boilers. The reason why economisers do not receive more consideration for Cornish boilers is possibly because the weekly steam requirement (where these boilers are installed) is often not very high. The capital outlay for an economiser, however, is not necessarily in proportion to the coal consumed by the boiler.

Boiler for boiler, the Economic is more efficient than the Lancashire, and to attain anything like parity between the two types it is necessary for the Lancashire to have an economiser. The Economic boiler has a quicker response to changes in steam demand, but has not as high a steam reserve as the Lancashire boiler.

Vertical boilers, apart from the multi-tubular type, are not very efficient, and are generally limited to works in the ceramic industry having low steam requirements, of the order of 500 to 1,500 lb./hr.

Economisers and Superheaters

Dealing with economisers and superheaters, it is stated that the introduction of economisers and superheaters has not been as great as it might have been, for both improve efficiency irrespective of bad operation. He points out that the emphasis today is upon mechanical stokers and says that the factors which determine the selection of mechanical stokers are the type of boiler, the required steam output, whether or not the demand is for a sudden heat peak, the type of boiler fuel available, the boiler draught and the boiler site. He deals with the question of smoke abatement, pointing out that not only does smoke emission create nuisance, but in addition it indicates low boiler performance.

He illustrates boiler plant improvements by three case histories which he deals with in terms of cost and performance. On the question of steam distribution he says:

Pressures

One of the first things to be considered in the use of steam is its pressure. When used for drying, low pressure—generally speaking—is better than high pressure, because there is more latent heat in steam at low pressure than at high. There may, however, be special circumstances in some drying practices where the temperature of the steam is important, in which case high-pressure steam might be used. Where steam is used to produce power, the inlet pressure to the engine should be high, and the outlet, or back, pressure as low as is practicable. These limits are governed, however, by the condition of the boiler and engine and by the process requirements. In our industry we refer to steam as high pressure if it is at 40 to 50 lb./sq. in. for process and, say, at 200 lb./sq. in. for power and the back pressure, or exhaust pressure, is usually between 2 and 5 lb./sq. in.

The process steam is required mainly for drying and for space heating; and, of the various methods of drying by steam in the heavy clay and refractories section, the hot floor is the least efficient. It is therefore reasonable to assume that there could be improvements in the use of steam for this purpose. Blowing steam through open ends under the floor is wasteful because, more often than not, all the latent heat in the steam is not given up under the floors. When practicable, the steam heat should be supplied below the floors through coiled pipes fitted with steam traps.

Investigations are often carried out relating to the performance of the boilers, but very little is done to show how the steam is utilised. The first step towards improving the steam utilisation on the works should be to measure the steam flow to the various sections of the works and to the various pieces of equipment (for example, dryers) and to draw up a flow diagram. Each section of the diagram should contain as much information as possible, and for a dryer, for example, at least the following items should be included.

STEAM FROM BOILER FOR DRYING

1. Steam supply (lb./drying hour)
2. Steam (per cent. of boiler output)
3. Heat supplied by steam (therms/hour)
4. Steam supplied per ton of clay, or per 1,000 bricks (lb.)
5. Heat supplied per ton of clay, or per 1,000 bricks (therms)
6. Cost of steam/hour (shillings)
7. Cost of steam per ton of clay, or per 1,000 bricks (shillings)
8. Basic efficiency of dryer
   (a) Dryer only
   (b) Overall taking boiler efficiency into account.

In addition to the above information, which is for a specific piece of equipment, a steam flow diagram will show, for example, whether a particular process, or section of the works, is having sufficient steam or whether the steam may be too much in other directions. The information will be useful for other reasons such as: (i) works costing, (ii) in deciding whether the use of steam for a particular process could be extended or replaced by, say, electricity or gas, (iii) where extensions to the works are visualised.

On many works requiring power and process heat these are produced as a combined system. There is no doubt that under the right conditions and properly operated, the system is a means of producing cheap power. Often where the system is not properly balanced, surplus exhaust is blown to atmosphere. In general, such a practice cannot be condoned, but some of our investigaions have shown that, within limits, it may pay under certain conditions to produce some power slightly in excess of a power-process heat balance and to blow the surplus exhaust steam to atmosphere. There are, however, few works where surplus exhaust could not be put to some useful purpose. On one works investigated, surplus exhaust was used in a calorifier system to heat a block of offices which had been previously heated by open fires.

In conclusion he makes acknowledgment to Dr. A. T. Green, O.B.E., Director of Research at the British Ceramic Research Association, for permission to publish his article.

DEPRECIATION AND MAINTENANCE OF POTTERY MANUFACTURING EQUIPMENT

(Continued from page 133.)

such charges had the effect of increasing the capital cost, and as the extension of the laboratory caused some of the company's own workpeople to be detailed to take part in the extension operations the payroll was dissected and a transfer made from wages account to the buildings account.

As already mentioned, the cost of repairs is an important factor to be taken into consideration when deciding the method of computing and recording depreciation of manufacturing equipment, and the next article in this series will include an example indicating the practical application of the "percentage" method as applied to mix-mullers and pulverising machinery.

CERAMIC PATENTS

POTTERY-MAKING MACHINES. Edward and Jones Ltd., B.P. 663,306. In this patent is described a pressure plate on the front cover plate of a power-driven machine such as a jigger, which stops the machine immediately in case of any emergency.

Pallets for moulding tiles. Marley Tile Co. Ltd., B.P. 663,310. Here the pallet plate is strengthened by using a stiffening plate having projections pressed out of its plane. The reinforcing plate in turn is welded to the pallet plate along the projections and then the two plates are welded together along their periphery.

De-airing clay. Edward and Jones Ltd., B.P. 663,329. In these machines clay and similar materials have their air removed in a plant which is in reality a feed barrel and a vacuum chamber. The material is fed into the latter by means of a perforated plate in which the holes may be varied in size according to the material. Variation may be carried out by using two similar plates, one which can be rotated relative to the other, whilst the material itself is cut by rotary motions before being extruded into the vacuum chamber.

Supporting pottery in the kiln. J. Hewitt and Son (Fenton) Ltd., B.P.

660,893. In this case teeth or projections with cavities are superimposed on their upper faces to support detachable pointed studs. These latter support directly the plates.

Water-resistant porous medium. U.S.P. 2,541,838. In this application casings made from ceramic bodies and used for radio equipment are rendered permeable to gases but impermeable to water by soaking in a 2-4 per cent. solution of a silicone resin in a suitable solution such as naphtha, after which they are baked for from 2-5 hours at 120-160° C.

Resin-bonded abrasive particles. The Carborundum Co., U.S.P. 2,559,665. Abrasive particles such as alumina and silicon carbide are mixed with a solution of furfuraldehyde and then is added a mixture of a P F resin and cryolite. Next is added an aqueous emulsion of a thermo-plastic resin such as polyvinyl acetate, which is deposited on top of the resin whilst another coat of this resin is deposited on the thermo-plastic resin. Alternatively after the cryolite addition the thermo-plastic resin may be deposited in powder form. The material is then dried, moulded, and cured to give an abrasive wheel which gives a finish equivalent to that produced by a rubber-coated wheel.

AMERICAN CERAMIC SOCIETY

THE titles of papers, published in the September, 1952 issue of the *Journal of the American Ceramic Society*, are as follows:

Thermal Expansion of Some Simple Glasses, by M. D. Karkhanavala and F. A. Hummel (Division of Ceramics, the Pennsylvania State College, State College, Pennsylvania).

Flow Characteristics of Fire-clay Refractories at High Temperatures, by Paul G. Herold and Christen Knudsen (Department of Ceramic Engineering, Missouri School of Mines and Metallurgy, Rolla, Missouri).

Improved Design of Apparatus for Measuring Thermal Conductivity of Refractories and Insulation at High Temperatures, by V. J. Duplin, Jr., and E. S. Fitzsimmons (Research and Development Laboratory, The Babcock and Wilcox Company, Alliance, Ohio).

The Behaviour of Glass Bottles under Impact, by R. E. Mould (Preston Laboratories, Butler, Pennsylvania).

Observed Direction of Leader Cracks from Hinge Failures of Glass Bottles, by H. M. Dimmick (Preston Laboratories, Butler, Pennsylvania).

Reactions During Sintering of a Zirconium Carbide-Niobium Cermet, by W. G. Lidman and H. J. Hamjian (Lewis Flight Propulsion Laboratory, National Advisory Committee for Aeronautics, Cleveland, Ohio).

Effect of Residual Compressive Stress in a Hotel-China Glaze on some Physical Durability Properties of the Glaze, by W. J. Koch, C. G. Harman, and L. S. O'Bannon (Ceramic Division, Battelle Memorial Institute, Columbus, Ohio).

The British Ceramic Society—Pottery Section.—The next meeting of the Section will be on the 10th November, when Professor Vick will present his paper, "Electrical Properties of Non-metallic Solids."

THE BRITISH CERAMIC SOCIETY

THE Autumn Meeting of the Refractory Materials Section will be held at the Royal Sanitary Institute, 90 Buckingham Palace Road, London, S.W.1, on Wednesday, 5th November, and on the morning of Thursday, 6th November, when the following papers will be presented:

"Practical and Theoretical Aspects of the Hot Pressing of Refractory Oxides," by P. Murray, E. P. Rodgers and A. E. Williams.

"Vapour Pressure Moisture Characteristics of Clays and their Relation to Plasticity," by B. Vassiliou and J. White.

"The Behaviour of Silica Bricks when Reheated," by W. Lewcock and J. H. Wylde.

"The Quartenary System CaO-Al_2O_3-TiO_2-SiO_2. I. The Ternary System Anorthite-Sphene-Silica," by Y. M. Agamawi and J. White.

"Some Contact Angle Measurements of Slags on Solid Surfaces," by Dr. Helen Towers.

"Diffusion Concepts in the Slagging of Refractories," by L. Reed and L. R. Barrett.

Mr. A. Smart. The Electric Furnace Co. Ltd., Netherby, 161 Queen's Road, Weybridge, Surrey, announce that Mr. A. Smart has been appointed a director.

Ceramics Exhibition. A "Ceramics in the Home" exhibition, sponsored by the *Observer* and designed and constructed by Cockade Ltd., designers and master modellers of South Kensington, opened on 30th September at Charing Cross Underground Station. The exhibition will be open daily, excluding Sundays, from 11 a.m. until 9 p.m. until 1st November. Admission is free.

ADVERTISERS' INDEX

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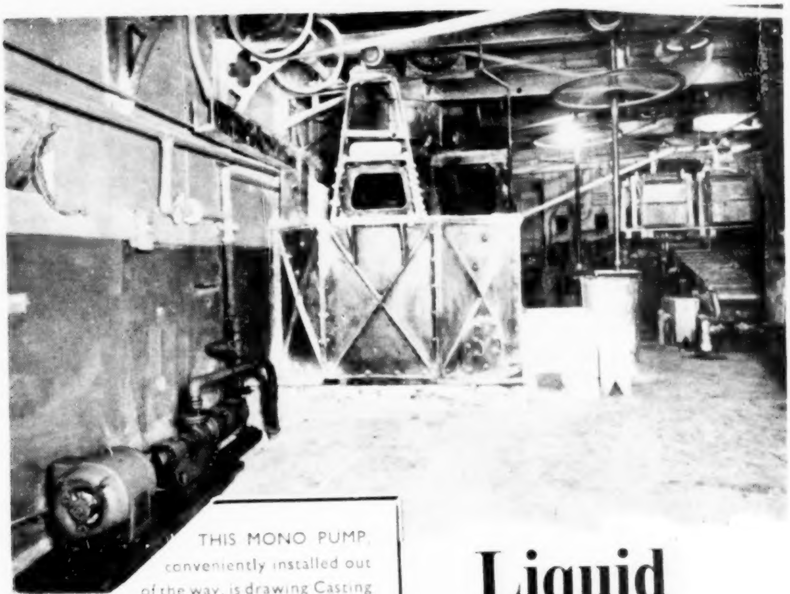

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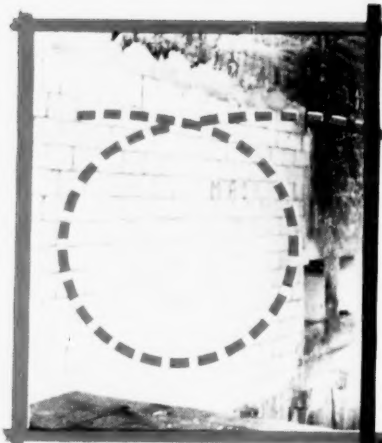

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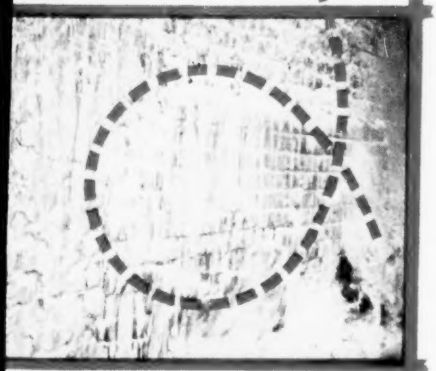

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